

Influence of tubular initial conditions on two-particle correlations

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Abstract.

A *unified* description of the near-side and away-side structures observed in two-particle correlations as function of $\Delta\eta - \Delta\phi$ is proposed for low to moderate transverse momentum. It is based on the combined effect of tubular initial conditions and hydrodynamical expansion.

1. Event-by-event 3+1 hydrodynamics

1.1. Overview of codes

One of the most striking results in relativistic heavy ion collisions, at RHIC and the LHC, is the existence of structures in the two-particle correlations plotted as function of the pseudorapidity difference $\Delta\eta$ and the angular spacing $\Delta\phi$. These structures may have a common hydrodynamic origin: the combined effect of longitudinal high energy density tubes (leftover from initial particle collisions) and transverse expansion. In order to compare with the data mentioned above, event-by-event 3+1 hydrodynamics must be used. In this type of approach, some initial conditions are generated, an hydrodynamics code is run and results are stored; this is done many times thus mimicking experience.

This method has been developed since 2001 by the brazilian collaboration SPheRIO [1, 2] (some typical results can be seen in [3, 4, 5, 6]). It has been also studied since 2007 by of H.Petersen et al. [7]. In 2010, K.Werner et al. [8] and B.Schenke et al. [9] have also started to use this method. All groups except the last one assume an ideal fluid. (Recently, various groups have also been working on event-by-event 2+1 hydrodynamics, see e.g. [10, 11].)

1.2. Results on two-particle correlations

In the NeXSPheRIO approach, initial conditions, generated with the NeXus code, have tubular structures and two particle correlations exhibit *near* and *away-side* ridges [6] as can be seen in figure 1. In the calculation by K.Werner et al., initial conditions, obtained

with the EPOS code, also have tubular structures and two particle correlations exhibit near-side [8] and *small* away-side ridges [12]. (The other two groups mentioned above have no result on two-particle correlations.)

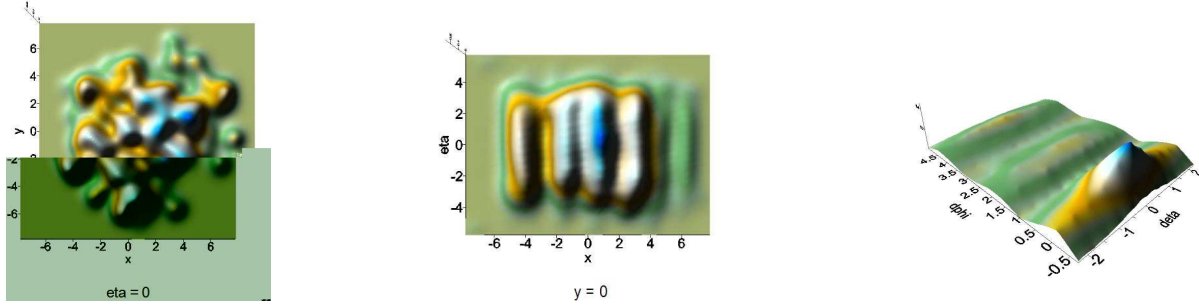


Figure 1. NeXSPheRIO central Au+Au collisions at 200 GeV A: initial energy density and example of resulting two-particle correlation.

In addition to reproducing both the near and away-side structures, NeXSPheRIO leads to good qualitative agreement with various data [13]: 1) for fixed p_t^{trig} and increasing p_t^{assoc} , the near-side and away-side peaks decrease for central collisions while for fixed p_t^{assoc} and increasing p_t^{trig} , the peaks increase, 2) when going from central to peripheral collisions, the near-side ridge decreases and the away-side ridge changes from double to single hump, 3) for a mid-central window, the away-side ridge changes from single peak for in-plane trigger to double peak for out-of-plane trigger while for central collisions, it is always double-peaked.

2. 2+1 hydrodynamics: one tube model

2.1. Central collisions

When using NeXSPheRIO, it is not clear how the various structures in the two-particle correlations are generated. To investigate this, we study the transverse expansion of a *realistic* slice of matter with only one tube (cf. figure 2). Longitudinal expansion is assumed to be boost invariant and freeze out to occur at some constant temperature.

As seen in figure 3, the single particle angular distribution has two peaks located on both sides of the position of the tube, more or less independently of the transverse momentum value. The peak spacing is $\Delta\phi \sim 2$ (this is not a parameter.) The resulting two-particle angular correlation has a large central peak at $\Delta\phi = 0$ (corresponding to the near-side ridge) and two smaller peaks respectively at $\Delta\phi \sim \pm 2$ (associated to the double-hump ridge). We have checked that this structure is robust by studying the effect of the height and shape of the background, initial velocity, height, radius and location of the tube [14].

The occurrence of the two-peak emission can be understood from figure 3. As time goes on, as a consequence of the tube expansion, a hole appears at the location of the

high-energy tube (see also [15]). This hole is surrounded by matter that piles up in a roughly semi-circular cliff of high energy density matter. The two extremities of the cliff emit more fast particles than the background giving rise to the two-peaks in the single-particle angular distribution.

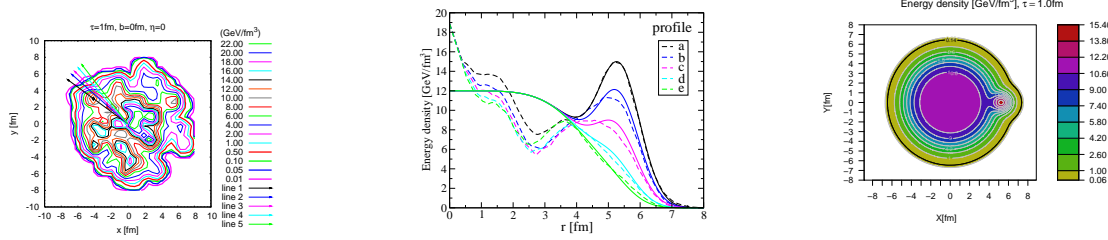


Figure 2. Left: choice of a typical NeXus tube located near the border. Center: choice of the energy density profile for the tube and averaged background (solid lines). Right: resulting transverse slice of matter.

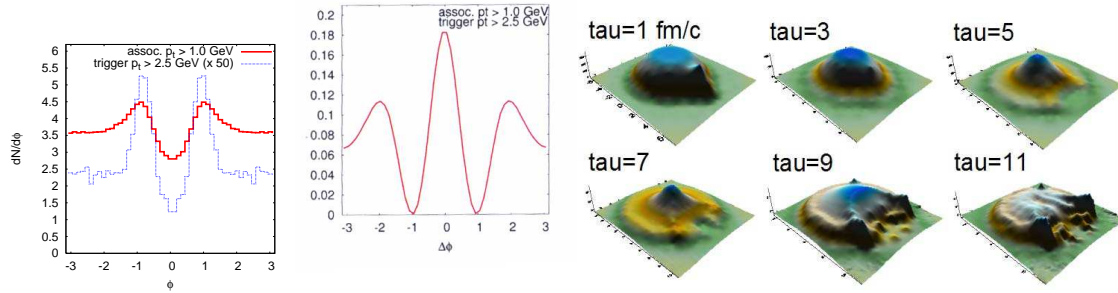


Figure 3. Left and center: single particle angular distributions and resulting two-particle correlation. Right: temporal evolution of the energy density in the slice.

2.2. Non-central collisions

We have also generalized this one tube model to non-central collisions [16]. To get final results, one must sum on all tube positions. For a given tube position, the single particle angular distribution is more complicated (the double-peak signature of the tube may be hidden by the elliptic flow) and the shape of the two-particle angular distribution depends on the trigger angle with respect to the reaction plane. After subtracting the elliptic flow and averaging on the tube angular position, the two-particle correlation is found to be single peaked for in plane trigger and double peaked for out-of-plane trigger in agreement with data.

2.3. Effect of several tubes

With these information, we can discuss what happens in a more complex event such as a NeXus event. Only the outer tubes need to be considered and will contribute with

rather similar two-peak emission pattern at various angles in the single particle angular distribution. The two-particle correlation has a well-defined main structure similar to that of a single tube surrounded by several other peaks and depressions due to trigger and associated particles coming from different tubes. When averaging over many events they disappear and only the main one-tube like structure is left.

3. Summary

Event-by-event 3+1 hydrodynamic with tubular initial conditions predicts two-particle correlations as function of $\Delta\eta - \Delta\phi$ in qualitative agreement with data. Using a simpler model, we have seen that near-side and away-side structures are related to a “two-horn” emission from each tube.

It has been suggested [17] that both these near-side and away-side structures are due to the triangular flow (v_3) produced by a triangular shape (or triangularity ϵ_3) present in the initial conditions. The one-tube model does have triangularity and triangular flow. However, one can add three inner tubes to cancel ϵ_3 and still have the same v_3 because only the outer tube contributes to this quantity. By removing this outer tube, leaving only the three inner tubes, one can have $v_3 \sim 0$ while ϵ_3 decreases a little but is non-zero. Both ϵ_3 (due to r^3) and v_3 are sensitive to external tubes however v_3 more so. As a consequence, on an event-by-event basis $v_3/\epsilon_3 = cst$ will not be satisfied. A more systematic study is in progress (see also [18, 11]).

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